STANFORD RESEARCH INSTITUTE
MENLO PARK, CALIFORNIA

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SUPPLEMENTAL REPORT
Covering the Period 1 October 1963 through 30 April 1964
Stanford Research Institute Project 4101

TECHNICAL PROBLEMS ASSOCIATED WITH COMMUNICATION SATELLITES

by

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Contract NASr-49(08)

Prepared for

National Aeronautics and Space Administration
Washington, D.C.

Approved by:

D. R. Scheuch, Executive Director
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I OBJECTIVE

The objective of this project was to explore several technical problems associated with the development of commercial communications satellite systems. These problems were:

(1) What satellite channel capacity will be required during the next several years based on present distributions of traffic and expected growth rates?

(2) What modulation method is most suitable considering the operational requirements to be met by the system, or systems, and considering the possible evolution of satellite systems from one set of orbit parameters to another?

(3) What effect will a large number of passive reflectors--either Echo-type balloons, or dipoles--have on optical astronomers?

(4) How effective will newly developed echo suppressors be in eliminating the undesirable echo present in telephone channels supplied by a stationary satellite from both an objective and subjective viewpoint?

II WORK PERFORMED DURING THE REPORT PERIOD

This Letter Report covers Amendments 2 and 3 to NASA Contract NASr-49(08) which increased contract funds by approximately $2,000 and extended the termination date to 30 April 1964.

The additional funds and time were utilized for: consultation for NASA in New York and Washington, D.C. by the project leader and principal investigator under this contract, Richard G. Gould; travel expense associated with this consultation; and clerical support during the period.

Meetings were held either at the offices of the Long Lines Division, AT&T, in New York or of the FCC in Washington. The subject of these meetings was, in all cases, the series of cooperative tests on time delay and echo suppression then being conducted by the AT&T with the guidance and approval of NASA, the FCC and other interested organizations.

The consultation for NASA had as its aim the review of test plans, the overseeing of the conduct of the tests, and the review of the results. In this regard, it can be said that useful information on the subjective effects of time delay and echo suppressor action was derived from these tests. Specifically, the fear was dispelled that a large proportion of customers would reject circuits with delays of 600 msec and fitted with even the best suppressors that have been developed to date--a fear based on one previous set of laboratory tests under these same circuit conditions.

A generally accepted conclusion drawn from these latest AT&T tests is that circuits with these delays have a high enough probability of being acceptable in commercial service to warrant providing them to the general public. To this end, a committee was formed of representatives of the organizations participating in these tests. This committee met to draft a Recommendation of the CCITT on the question of time delay and echo suppression. This Recommendation was concurred in, with only minor changes, by other interested organizations, and it was submitted to Study Groups XII and XVI of the CCITT, where it met unanimous approval essentially as submitted. This approval was ratified subsequently by the IIIrd Plenary Assembly of the CCITT and the Recommendation will appear in the record of the Plenary. It is included with this Letter Report as Attachment I.

The circuits to be offered shortly by the Communications Satellite Corporation via a stationary satellite will offer the best possible proving ground for customer acceptance of circuits with time delay.

Experience with these circuits over the next few years will aid in a choice of ultimate communication satellite system designs. Before these circuits are actually in service, and even after they are in service, additional laboratory tests should be conducted by interested organizations to add to the knowledge that can be derived from operational experience and to obtain answers to questions that cannot be resolved efficiently or rapidly by in-service tests.

ATTACHMENT 1

TO BE DISTRIBUTED ON : 11 June 1964 at : 10 a.m.

ROOM 5 - MAISON DES CONGRES

C.C.I.T.T.

STUDY GROUP XII

GENEVA - 9 - 12 JUNE, 1964

Temporary Document No.7-E

9 June, 1964

SOURCE : JOINT MEETING OF STUDY GROUPS XII AND XVI (GENEVA, 8 JUNE, 1964)

TITLE : DRAFT RECOMMENDATION G.1.114 (TO REPLACE THE TEXT IN AP III/46) AND DRAFT NEW TEXT FOR QUESTION 6/XII

COM XII-Temp.7-E

DRAFT RECOMMENDATION G.1.114

MEAN ONE-WAY PROPAGATION TIME

A. Limits for connections

It is necessary in an international telephone connection to limit the propagation time between two subscribers. Recent tests have shown that international connections probably will not cause adverse subscriber reaction due to the combined effect of delay and echo suppressors if the mean one-way propagation time*) is increased from near zero to the order of 150 ms. As the propagation time is increased beyond 150 ms, subscriber difficulties increase, and the rate of increase of difficulty rises, up to and including the maximum one-way propagation time tested, namely 400 ms. The C.C.I.T.T., therefore, provisionally recommends the following limitations on mean one-way propagation times when echo sources exist and echo suppressors are used.

a) Acceptable without reservation, 0 to 150 ms.

b) Provisionally acceptable, 150 to 400 ms. In this range connections may be permitted, in particular, when compensating advantages are obtained.

c) Provisionally unacceptable, 400 ms and higher. Connections with these delays should not be used except under the most exceptional circumstances.

Until such time as additional, significant information permits administrations to make a firmer determination of acceptable delay limits, they should proceed with caution and with full cognizance of the data in annexes ..... in selecting, from alternatives, plans involving delays in range (b) above.

B. Values for circuits

In the establishment of the General Interconnection Plan within these limits the one-way propagation time of both the national extension circuits and the international circuits must be taken into account.

a) National extensions

The main arteries of the national network should consist of high-velocity propagation lines. In these conditions, the propagation time between the international centre and the subscriber farthest away from it in the national network will probably not exceed :

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*) Mean of the times in the two directions of transmission.

12 + (0.0064 x distance in statute miles) ms

or 12 + (0.004 x distance in kilometres) ms

Here the factor 0.0064 (0.004) is based on the assumption that national trunk circuits will be routed over high-velocity plant (155 statute miles/ms or 250 km/ms). The 12 ms is an allowance for terminal equipment and for the probable presence in the national network of a certain quantity of loaded cables (e.g. 3 pairs of channel translating equipment plus about 100 miles (160 km) of H 88/36 loaded cables. For an average-sized country the one-way propagation time will be less than 18 ms.

b) International circuits

International circuits will use high-velocity transmission systems, and the one-way propagation time or velocity that should be assumed for planning purposes are :

1. Terrestrial (including submarine cable)

100 statute miles/ms (160 km/ms)

This propagation velocity includes an allowance for terminal and intermediate multiplex equipment likely to be associated with a transmission line.

2. Satellites

The mean one-way propagation time between earth stations for two illustrative single-hop communication satellite systems are :

Moving satellite (at 8,750 miles or 14,000 km altitude)	110 ms
Geo-stationary satellite (at 22,500 miles or 36,000 km altitude)	260 ms

The one-way propagation times do not include any allowance for the distance from the earth stations to locations where the satellite circuits can either be extended on other international transmission systems or switched to other national or international circuits. These additional times should be taken into account for planning purposes. The distances between earth stations which are practical depend not only on the altitude of the satellites but also on the orbits and positions of the satellites relative to the earth stations.

Note - The one-way propagation time referred to above is the group delay as defined in the List of Definitions of Essential Telecommunication Terms (Definition No. 04-17), calculated at a frequency of about 800 c/s.

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QUESTION 6/XII (Suggested new text)

Subscribers' tolerance of lengthened propagation time, echo and echo-suppressors.

Parts a) and b) unchanged (See Red Book Volume V, page 603)

c) What is the maximum propagation time for which echo-suppressors complying with Recommendation G.151 would be satisfactory? The effects of practically occurring ranges of relevant factors such as transmission losses, return losses, circuit noise levels and types of subscribers' sets and lines, should be considered.

d) What transmission performance can be expected from telephone connections having mean one-way propagation times of the order 150 ms and upwards? The following transmission factors are likely to affect the performance and appropriate ranges of their magnitudes should be considered.

1. The presence of several circuits, each having a separate pair of echo-suppressors, connected in tandem. The cases of similar-type suppressors and of different types in the several circuits require consideration.

2. The presence of appreciable end-delay.

3. Transmission losses of the two-wire extensions at each end of the four-wire part of the connection.

4. Return losses of various magnitudes and loss-frequency characteristics at the two ends.

5. Circuit noise level, including the effects of very low levels achieved by companding.

6. Echo-suppressors of different types at the two ends of the international circuit.

New Annex (to Question 6/XII)

When telephone connections of increasingly long propagation times are considered, certain problems arise that are peculiar to certain ranges of propagation time. Under practical conditions that apply in public telephone networks, speech signals will be reflected from the remote end and be returned to the customer while he is talking; these will appear to him as

an augmentation of sidetone or as an echo. If the propagation time is very small the amount by which the reflected signals must be attenuated to be unobjectionable can readily be made sufficient; the maximum propagation time for which this is the case is the subject of Recommendation G.121 B and the present question part a) is concerned with the revision of this information. To use such information, it is necessary to express return losses which are frequency-dependent by a single figure suitably averaged over the transmitted frequency band; this problem is the subject of part b) of the present question.

When the propagation time exceeds the value discussed above, it is necessary to furnish the circuits with echo suppressors and the type described in Recommendation G.151 will be satisfactory up to a certain propagation time which it is not, at present, possible to define; part c) of the present question is concerned with the definition of this value of propagation time. Recent tests have shown that the performance of circuits equipped with improved types of echo-suppressor and having mean one-way propagation times of the order of 150 ms is practically as good as that of circuits otherwise identical but having a very short propagation time; part d) of the present question is concerned with the further study of problems associated with the use of connections having propagation times of this order and upwards.

Annex 1 given on page 61 of COM XII-No.92 will need slight revision to correspond to the division into parts c) and d) as well as a) and b). Present a).2 becomes c) and d). or d).